Tangible interaction:
A new approach to customer participatory design
Focused on development of the Interactive Design Tool

Jae-Hyung Byun*, Myung-Suk Kim**

* Division of Design, Dong-A University, 1 Dongdaesin 3-ga Seo-gu Busan KOREA, bion@conceptmaker.com
** Dept. of Industrial Design, Korea Advanced Institute of Science and Technology, 373-1 Guseong-dong Yuseong-gu Daejeon KOREA, mskim@kaist.ac.kr

Abstract: Participatory design is an effective method for gathering customer’s practical needs in design process. Participatory design for general customer who are not familiar with existing design activities requires an alternative tool to express their design needs effectively. Although computer visualization is an efficient tool, it is not easy for general customer because it requires learning process of complex software. So, more intuitive interface style is required for an alternative method.

This study intends to investigate applicability of the Tangible Interaction as a tool for customer participatory design by suggesting direct manipulation method which identifies control mechanism with the mental model of customer. The Interactive design tool developed in this study is a furniture layout system and a virtual model house using PC-based image tracking system and its application. The tool uses physical models which are identical to virtual models to make it possible for general customer to control intuitively. Customer can make virtual models in virtual space by manipulating physical objects directly in real world.

Result of this study is considered as useful method in two aspect. The first is that it can provide a rapid visualization method for customer participation. Combining soft models with virtual ones can reduce time and cost in making physical mock-ups. Designer can make soft models and modify it easily. Modification of virtual models can be made easily too. The second is that it can minimize the gap between controlling mechanism of existing interface and customer’s mental model. Customer can manipulate virtual models without any learning process of the tool. Method of this study can be applied for customization of consumer product by participating in design process by customer themselves. So, these can be used as an alternative design tool for general customer to express their design needs in participatory design process.

Key words: tangible interaction, product design, participatory design, interactive, customization

1. Introduction

Mass customization is an alternative tool for management to satisfy various needs of customer, and commercialized in many companies with the help of development of manufacturing and information technology. The most important thing for mass customization is understanding what customer really wants. Methods for understanding needs of customer are developed in various way including questionnaire, interview and observational research as an advanced tool. Nowadays, taking customers directly part in design process is tried as a positive notion and practical studies are undergoing.
The traditional design method of ‘Drawing by hand’ is going to be transferred to new tools as time goes. Because ‘Drawing by hand’ requires special technique and talent, education and exercise in long period are required to be a designer. So, taking general customer part in design process requires to offer adequate design tools for general people who are not familiar with specific design techniques. The problem of ‘Drawing by hand’ lies in expressing 3 dimensional object in mind into plane figure on 2 dimensional surface. Instead of drawing by hand, visualizing object in 3 dimensional form like dummy mock-up is not efficient in terms of time and cost. Therefore, A new design tool which can reduce expenses is required.

This study intends to investigate applicability of the Tangible interaction as a method for customer participatory design by suggesting direct manipulation method which identifies control mechanism of complex system to the mental model of customer. And also this study focuses on development and application of the interactive design tool which can be used as an alternative and practical tool for participatory design for general customer who are not familiar with traditional design activities.

The process of this study starts from reviewing theoretical issues related to the participatory design and establishing requirements of design tool which meet characteristics of customer. In order to meet these requirements, the Tangible interaction is adopted as an alternative interface method to make the interactive design tool. We are going to make the Interactive Design Tool using PC-based image tracking system and physical soft models, and consider its application area in practical. The quantitative evaluation of the tool is not included in this study yet.

2. Participatory design and methods

The participatory design is a kind of the collaborative design which enables cooperation between design team and users. Studies for the collaborative design including CSCW(Computer-supported Collaborative Work) and CSCD(Computer-supported Collaborative Design) were focused on cooperative design process using network technology between remote work sites. Participants were composed of designers and engineers who are using graphic tools and message window in the cyber space[1]. Although the participatory design is tried in various field of design, participants and method are dependent upon the case. In case of city planning, experience of participants is not important. On the contrary, participating in design process of consumer product requires more experience of customer in terms of design activity[2]. The most important problem is that general customers are not expert in design activity.

Methods used in architecture including questionnaire, interview, sketch, model, CAD(Computer Aided Drawing), and model house can be utilized in consumer product. These are classified into active and passive methods. The active method includes workshop and simulation. Gathering information like questionnaire, interview and observation is the passive one[3]. Simulation is regarded that can be utilized in participation of non-expert because it makes easy to mediate opinions by visualizing reality. So, tool for participatory design for general customer requires a form of simulation and should consider characteristics and constraints of the user.

2.1 Considerations for participatory method in product design

Participatory design in consumer product is letting general customer to take part in the middle of design process directly. General customers are not familiar with traditional design activities which designer uses, like idea sketch or modeling. It is unreasonable to expect for general customer to have such a communication
capability equal to professional designer. More direct and familiar communication methods are required for
general customer to express their design needs. ‘Drawing by hands’ can be achieved by long period of experience
and education. Writing has difficulties in expressing thinking in mind into practical form. So, more direct and easy
way of communication is needed instead of sophisticated techniques. One of the most familiar way of making 3
dimensional objects is a block-building toy, Lego™, for children. Main characteristics of this toy can be regarded
as direct manipulation of components in 3 dimensional way to make 3 dimensional object. ‘Drawing by hand’ has
intermediate stage of transferring 3 dimensional object in mind into 2 dimensional shape on plane surface. And
reinterpretation of 2 dimensional picture into 3 dimensional object is performed in the mind of drawer. Difficulties
in interface goes on increasing in proportion to interpretation stage. Therefore, an alternative method of direct and
3 dimensional way for general customer is required.

2.2 related works

One of practical cases of participatory design tool for
general customer may be the Concept generation
toolkit(Sanders, 2001)[4] which is based on the
assumption that every person is creative(figure.1). The
toolkit is made for general people who are not familiar
with design activities, and uses a method of storytelling
to express experiences of participants instead of drawing.
Participants make storyboard of memories in mind using
prepared pictures, photos and small objects. This can
make easier for participants to express their thinking in
mind by using prepared toolkit. But, There remains still
some problems. The most inconvenient thing is that the
result should be interpreted by designers for further
design process. The design toolkit for classroom
environment(Nam, 2002)[5] is a more direct method to
achieve ideas of desirable classroom environment from
primary school students. Participants can compose
favorite layout of classroom by handling prepared 3
dimensional miniatures which represent real environment.
Children can express their thought like playing block
building toy and do not need learning process(figure.2).

Considering above cases, the participatory design tool
for general customer should utilize physical material and reduce learning process of the tool. Beside of selecting
familiar way of manipulating, transformation of data into digital format is required. The more number of
participants increase, the more data processing is required. Results of participatory design should be interpreted
and sent to other designers and engineers for feedback in design process. The result of physical design tool should
be transformed into digital media for further processing. For the purpose of direct data acquisition at customer
level, more intuitive interaction style is required to reduce intermediate interpretation stage by designers.
The Tangible Interaction is a new approach for intuitive and physical interaction style. The Physical interface(Sato, 2001)[6] and the seamless interface(Ishii, 2001)[7] are understood as similar meaning. These are advanced interaction style which use physical sensors of human and alternative modalities instead of traditional GUI(Graphic User Interface) depending on mouse and 2 dimensional display. The basic concept of the tangible interaction is to suggest an intuitive interface by providing physical and familiar way of control to reduce learning process of system.

Although 3 dimensional physical mock-up is effective for customer to understand final design of product which is not existent, mock-up is not advantageous due to production cost and time. And mock-up can not be modified immediately on customer’s demand. 3 dimensional computer modeling can simulate final design of product effectively and be modified immediately. But this method requires experienced assistant for customer participation because general customer can not operate themselves. This means that there should be intermediate communication channel. A new design tool which uses 3 dimensional simulation and transforms customer’s physical manipulation into digital data in real time can reduce this problem. For this kind of method, an intuitive interaction style for direct manipulation by customer themselves is needed. A new approach to 3D modeling using electronic building block(Anderson, 2000)[8] suggests a familiar physical modeling method like Lego™ block(figure.3, 4). Operator can make virtual models without learning the software. This modeling tool has electronic circuits in each block and detects electric signals to recognize modeling status when operator composes blocks. Although the approach of Anderson(2000) has a merit of reducing learning process because it is familiar to general people, it is expensive and restricted by number of block.

Methods mentioned above are compared in terms of material, technological difficulty, production cost and need of additional interpretation(table 1). Methods of Sanders(2001) and Nam(2002) are very efficient in terms of production cost, but additional process for interpretation and transformation of results is needed. Although Anderson(2000)’s is a direct method for utilizing results, distribution of the tool for practical use in the field of consumer product design will be restricted due to its high production cost and technological difficulty. So, a new approach for practical use is needed.

Table 1. Comparison of methods of participatory design

<table>
<thead>
<tr>
<th>method</th>
<th>material</th>
<th>Technological difficulty</th>
<th>Production cost</th>
<th>Need of additional interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanders(2001)</td>
<td>paper, fabric, etc</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Nam(2002)</td>
<td>Paper model</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Anderson(2000)</td>
<td>Electronic circuit</td>
<td>high</td>
<td>high</td>
<td>low</td>
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</table>
3. Development of the Interactive Design Tool

This study defines the Interactive design tool as a tool for visualize and modify design alternatives by direct manipulation of computer system by participants themselves. The basic concept of the interactive design tool is to suggest a new interaction style of manipulation which is familiar to general customer and make it possible to express their design needs by themselves. Aims of a new approach are to suggest intuitive interaction style for general customer to use without any difficulty, and to make it possible to popularize the tool in the design field for practical use at reasonable condition.

3.1 Requirements for the Interactive design tool

For development of the Interactive design tool, we need to meet some requirements of customer side as well as developer. Requirements of the tool in the aspect of customer are as follows.

- **familiarity**: Familiar operation method which is experienced and understood by user easily should be used.
- **immediate feedback**: Delay in feedback which causes inconvenience and unnecessary action should be minimized.
- **error tolerance**: We should keep in mind that general customers are not expert on the system. Mistakes in control should be allowed to prevent unexpected results.

Requirements in the aspect of developer are as follows.

- **ease of distribution**: The tool should can be made at low cost for distribution and practical use.
- **ease of modification**: The tool should can be modified at any time to meet customer’s request in parts or entire body.
- **immediate data processing**: The results which customer made should be gathered and processed immediately.
- **reducing interpretation process**: The results should be understood intuitively.

This study choose an PC-based image tracking system which incorporate physical model with virtual one using commercial software packages. Manipulating physical models which resemble block toy is familiar to general customer. So, it can minimize learning process. Incorporating virtual model with physical one can make it possible for designer to make simple physical models for reducing time and cost. And simple physical models can meet customer need of immediate modification.

3.2 Building the Interactive Design Tool

The Interactive Design Tool is based on a PC-based image tracing system. Customer can build virtual models using physical models without any help of instructor. The overall hardware structure of the system can be seen on [figure.5]. The camera attached to the PC tracks position and movement of physical blocks on the surface of the table. Detail shapes and colors are rendered on the screen via LCD projector. Details of system are following.

**Hardware**: The Interactive Design Tool is based on a PC and a USB camera. A LCD projector and a screen is used for display of rendered image. Video capturing board is not used. Tracking is performed by software.
Software: Macromedia Director Shockwave Studio™ is used for authoring and real-time rendering. TrackThemColors Xtra for Director is used for tracking physical objects. Virtual models are modeled, texture mapped and converted using 3D Max™.

Workbench: The workbench is a simple steel structure covered with glass and semi-transparent plastic sheet. A USB camera and lightings are located under the glass.

Physical models: Physical models are made of soft material including paper and soft form which is used in making rough model. It can reduce time and effort when making models. Pair of color indicators are attached to the bottom of models for tracking position (figure 6).

The Interactive Design Tool tracks 2 dimensional coordinates of physical models by tracking color indicators attached to the bottom of each objects. Each pair of color indicators is used to determine position and angle of objects. Position and angle data determines location and direction of virtual models in virtual space. Designer can assign virtual models to physical models easily. If there is needed to modify shapes or color of virtual models, designer can modify them in 3D modeling software (3D Max™) easily. Physical models which are assigned can be modified easily too. The overall data flow of the system is illustrated in [figure 7].

3.3 Application of the Interactive Design Tool

We made two applications using the Interactive Design Tool. The first is the furniture layout system which is composed of miniatures of system furniture as physical models. Customer can move and rotate miniatures and make up their favorite layout. Virtual models are moved and rendered in real time in the front of customer when they manipulate the system (figure 8, 9, 10).

The second is the virtual model house. The basic operation is similar to the furniture layout system except adding a view point of user. Customer can walk around...
in the virtual model house by simply moving a puppet (figure.11, 12). The view point of customer is displayed on the screen. The operation method is very simple like playing with a doll. Customer can look around and watch some spots of concern. In advance, customer can move walls or furniture to customize the house as they like. No assistance is needed too (figure.13).

4. Discussion

The basic concept of the Interactive Design Tool is to offer an intuitive interaction style by applying the tangible interaction. The tool does not require for customer to learn its operation method because it uses direct manipulation of physical models which are correspondent to virtual models. Physical models are metaphor of virtual models. They present only size and rough shape by which customer can expect final design in virtual space. This means that customer can accord his mental model with virtual model to predict final result. And physical models can be made and modified easily on demand of customer because they are made of soft material. The Interactive Design Tool can be compared to other methods in terms of requirements described above (table 2).
tool has some strong points in the aspect of distribution, ease of modification and data transformation. Comparison was performed by the author based on interviews with participants who are asked to experience the tool qualitatively.

<table>
<thead>
<tr>
<th>Table 2. Comparison of the Interactive Design Tool with related works</th>
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<tr>
<td>---</td>
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<tr>
<td>familiarity</td>
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<td>immediate feedback</td>
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<td>error tolerance</td>
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<td>ease of distribution</td>
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<td>ease of modification</td>
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<tr>
<td>immediate data gathering</td>
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<tr>
<td>reducing interpretation process</td>
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(Scale : good ; ● > normal ; ○ > bad ; ● )

5. Conclusion

Understanding customer and their needs is a key factor to meet their various requirements about design. As a active way of understanding customer, customer participatory design is a useful method for the purpose. Although letting customer to take part in design process is useful, there are some problems in practical application. One of them is that customer are not experienced in design activity. So they can not express their design needs and have difficulties in communicating with designers or engineers. Although development of computer technology makes it easier to visualize design alternatives in virtual space before making physical models, it is not easy for customer to learn its operation to express by themselves. The Tangible Interaction can be used as an alternative way of interface method for general people to interact with computer systems and other applications.

The goal of this study is to investigate possibility of an efficient design tool for customer participation using the tangible interaction. We suggested the Interactive Design Tool which is using a PC-based image tracking system. And we made the furniture layout system and the virtual model house as its applications. Significances of the tool are as follows. Firstly, The tool provides a rapid visualization method for customer participation. Combining soft models with virtual ones can reduce time and cost in making physical mock-ups. Designer can make soft models and modify it easily. Detail design and reality can be achieved by computer rendering in virtual space. Modification of virtual models can be made easily too. Secondly, customer has no need for learning the system. Customer can manipulate the system in familiar and experienced way. The most important thing in developing some tools for customer participatory design is to provide intuitive ways of manipulating the system. If there are difficulty in using the system or need for other’s help, customer will shrink and hesitate to express their requirements in mind.

The limit of the tool presented above is that it is restricted to 2 dimensional position and movement. So, it can be applicable in the field of 2 dimensional design variations including furniture layout or interior design. In order to apply to consumer product design, 3 dimensional tracking system should be developed. Further study for 3 dimensional tracking system using multiple camera or 3 dimensional attaching system using physical electronic contacts are being considered by the author.
References